GEOLOGY, ENERGY, AND MINERAL (GEM) RESOURCE ASSESSMENT OF THE PRYOR MOUNTAINS GEM RESOURCE AREA (GRA) MONTANA, INCLUDING THE BURNT TIMBER CANYON WILDERNESS STUDY AREA (MT-060-205); THE PRYOR MOUNTAIN WILDERNESS STUDY AREA (MT-060-206); AND THE BIGHORN TACK-ON WILDERNESS STUDY AREA (MT-060-207)

PHASE I

Contract No. YA-553-CT2-1055

Prepared for:

U.S. Bureau of Land Management

Prepared by:

Tetra Tech, Inc.
Pasadena, California

September 1983

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EXECUTIVE SUMMARY

The U.S. Bureau of Land Management (BLM) has adopted a two-phase procedure for the integration of geologic, energy, and mineral (GEM) resources data concerning Wilderness Study Areas (WSAs). To facilitate this review, certain WSAs with similar geologic environments and mineral characteristics have been grouped together into larger GEM Resource Areas (GRAs). Using these guidelines, the Burnt Timber Canyon WSA, the Pryor Mountain WSA, and the Big Horn Tack-On WSA have been grouped together into the Pryor Mountains GRA. This report, which terminates the Phase I activities for the Pryor Mountains GRA, is an evaluation and interpretation of existing data concerning the GEM resource potential in the WSAs.

The Pryor Mountains GRA contains 3 WSAs: the Burnt Timber Canyon WSA (MT-060-205); the Pryor Mountain WSA (MT-060-206); and the Big Horn Tack-On WSA (MT-060-207). The three WSAs are contiguous, and are located in the BLM's Billings Resource Area, Lewistown District, Montana.

Areas of the Pryor Mountains GRA have been classified as having a high to moderate favorability for the potential occurrence of uranium. Vanadium, a strategic and critical mineral, has been identified as an accessory to uranium in this area. There is a high favorability for potential uranium and vanadium occurrences in the Madison Limestone-Amsden Formation contact paleokarst (classified 4D); this classification is based on abundant direct and indirect evidence (Worchola and Stockton, 1982). There is a moderate favorability for potential uranium and vanadium occurrences in the Lakota Sandstone and Tensleep Formations (classified 3B); this classification is based on indirect evidence (Garrand, Kopp, and Cohenour, 1982). Uranium and vanadium have been mined in the GRA in proximity to the WSAs (USGS, 1982; USBM, 1982). An interpretation of the geology of the region indicates uranium and vanadium may occur throughout the WSAs in the GRA.

The Pryor Mountains GRA also has a moderate favorability for the occurrence of gypsum and limestone (classified 3D); this classification is based on abundant direct and indirect evidence (Blackstone, 1940). The Chugwater Formation is considered to have moderate favorability for the presence of gypsum. Gypsum has been identified as a potential resource because of its common occurrence in the Chugwater Formation (Pierce, 1978). The Madison Limestone is considered to have moderate favorability for potential limestone resources (classified 3D); this classification is based upon abundant direct and indirect evidence. Limestone has been identified as a potential resource in the region because of the presence of the Madison Limestone, and because of the high quality limestone from similar geologic environments in other areas of the Rocky Mountains (Blackstone, 1940).

The potential occurrence of other GEM resources in the study area has a low favorability (classified 2C); this classification is based upon the geologic environment and inferred geologic processes identified in the WSAs. The potential occurrence of paleontologic resources in the study area is considered high based upon the high potential for the presence of vertebrate fossils in the Chugwater, Morrison, Cloverly, and Sundance Formations, as well as in caves associated with the Madison Limestone (Gilbert et al., 1978; Martin and Gilbert, 1978).

Additional geologic investigations would help supplement the GEM resource evaluations of the Pryor Mountains GRA. Detailed mapping of the paleokarst terrain within the area would help identify areas of potential uranium resources. The potential presence of gypsum and other mineralization resources could be more thoroughly evaluated by measuring thicknesses and facies changes in the Chugwater Formation. Additional understanding of the mineral resources of this area could be obtained by an in-depth review of the available literature by BLM personnel.

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GEM RESOURCE AREA
PRYOR MOUNTAINS

1.0 INTRODUCTION

1.1 Purpose of Study

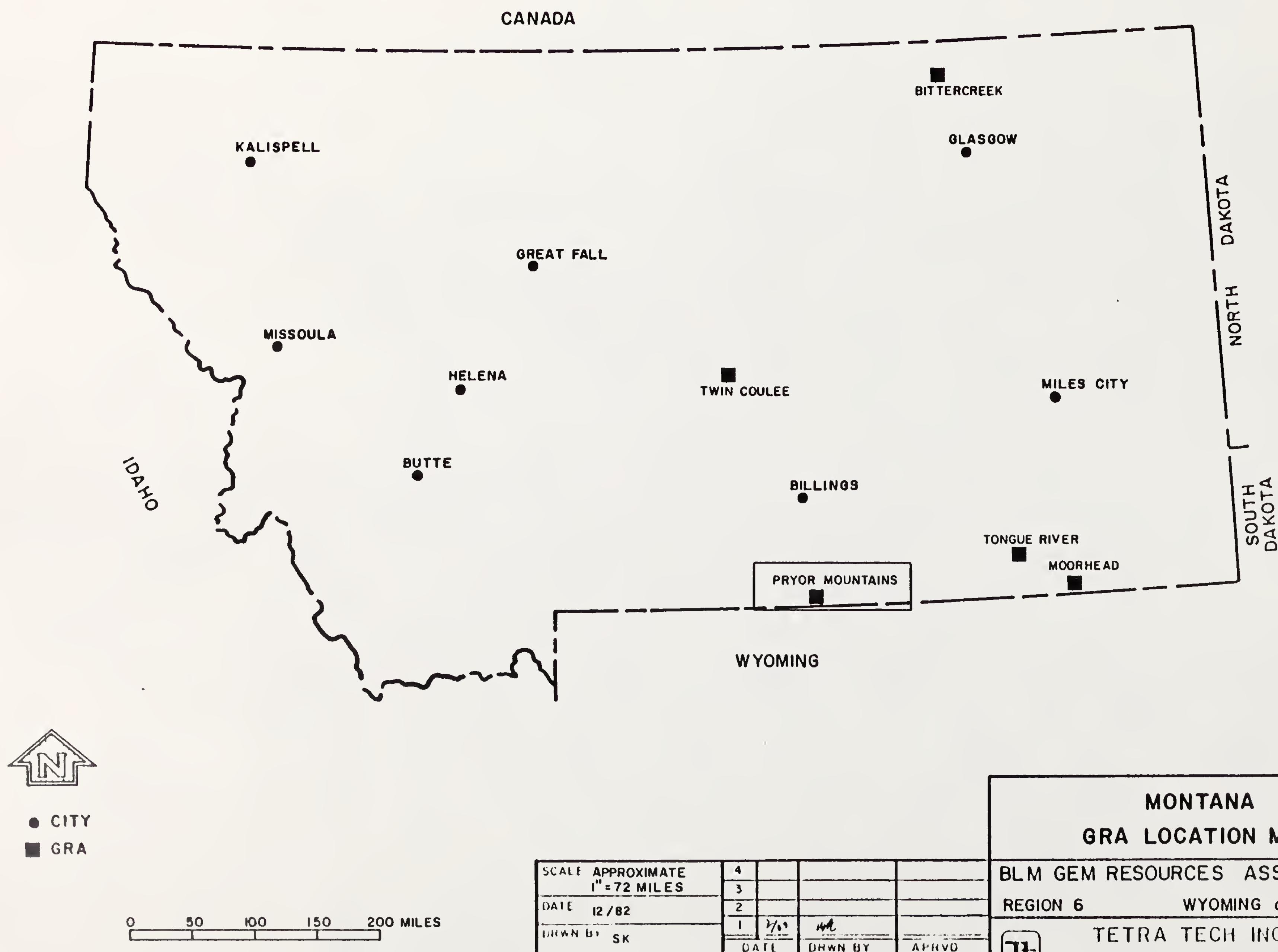
The U.S. Bureau of Land Management (BLM) has adopted a two-phase procedure for the integration of geologic, energy, and mineral (GEM) resources data for suitable/nonsuitable decisions concerning Wilderness Study Areas (WSAs). Phase I consists of a review and evaluation of existing data, resulting in an interpretation of the GEM resource potential of the WSAs. Phase II is designed to generate only the additional data required to support the GEM resource recommendations presented during Phase I. To facilitate this review, certain WSAs with similar geologic environments and mineral characteristics have been grouped together into larger GEM Resource Areas (GRAs). Using these guidelines, the Burnt Timber Canyon, the Pryor Mountain, and the Big Horn Tack-On WSAs were grouped into the larger Pryor Mountain GRA. This report, which terminates the Phase I activities for the Pryor Mountains GRA, is an evaluation and interpretation of existing data concerning the GEM resource potential in the WSAs.

The GEM resource evaluations for this study were performed by Tetra Tech, Inc. for the U.S. Bureau of Land Management, under Contract No. YA-553-CT2-1055. This study was completed in January, 1983.

1.2 Location and Access

This GEM report covers the area identified as the Pryor Mountains GEM Resource Area (GRA); the geographic location of the study area is shown in Figure 1.1, "GRA Location Map."

The Pryor Mountains GRA contains 3 WSAs: the Burnt Timber Canyon WSA (MT-060-205), the Pryor Mountain WSA (MT-060-206), and the Big Horn Tack-On WSA (MT-060-207). The Burnt Timber Canyon WSA contains 3,955 acres; the Pryor Mountain WSA contains 16,972 acres; and the Big Horn Tack-On WSA contains



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MONTANA
GRA LOCATION MAP

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FIGURE 1.1

4,500 acres. The WSAs are located between 108° 15' - 108° 25' west longitude, and between 44° 55' - 45° 12' north latitude. The WSAs are located in parts of Townships (T) 7-9 South (S), Ranges (R) 27-28 East (E), 6th Prime Meridian (P.M.), Carbon County, Montana, and in parts of T 58 North (N), R 95-96 West (W), Big Horn County, Wyoming. All three of the WSAs are located in the BLM's Billings Resource Area, Lewistown District, Montana. Figure 1.2, "Topographic Map," illustrates the topography of the GRA, as well as the location of the WSAs within the GRA.

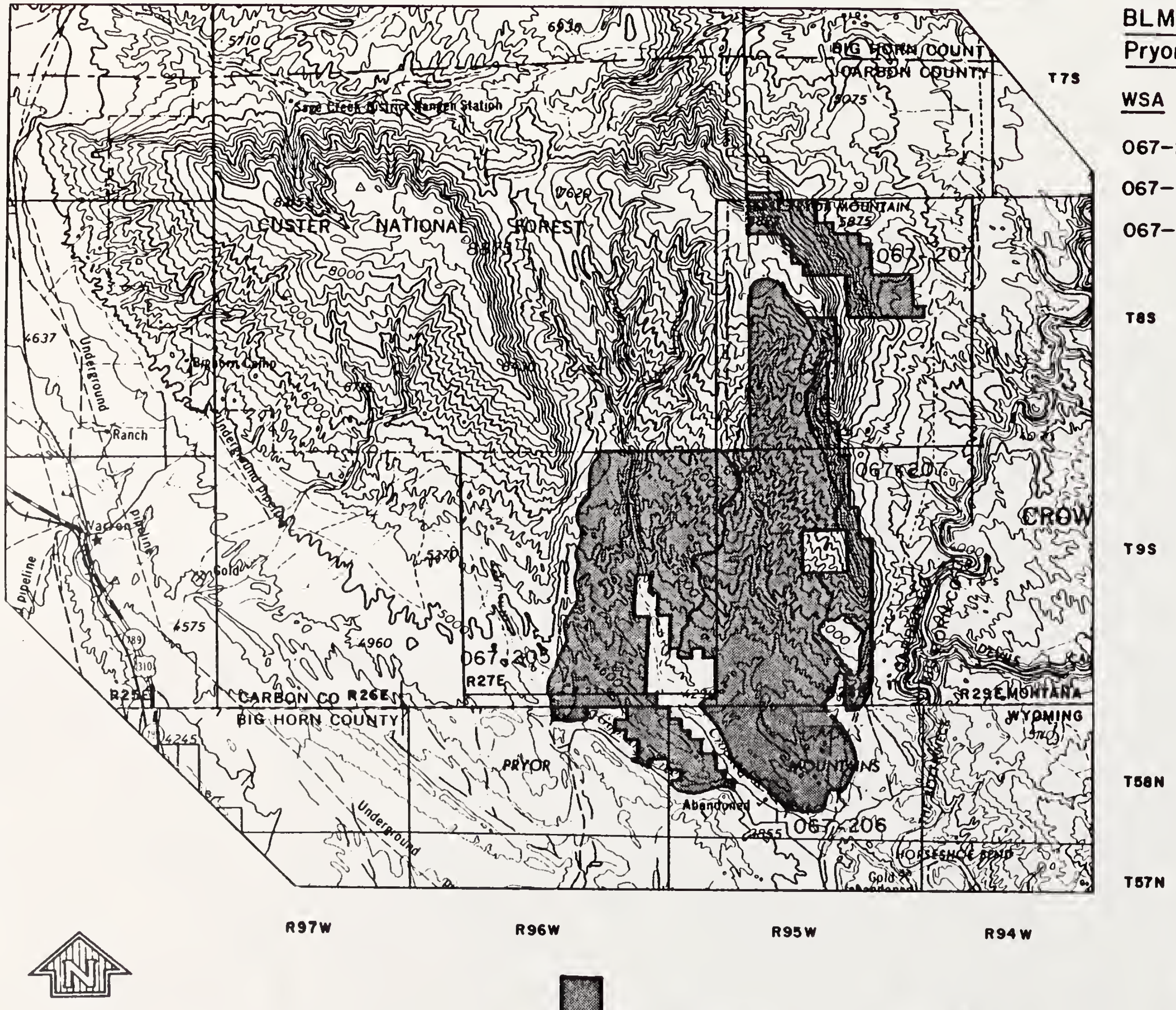
Access to the WSAs within the Pryor Mountains GRA is by county roads from Lovell, Wyoming; graded roads and unimproved jeep trails also border the margins of the Pryor Mountain WSA and adjacent areas.

1.3 Basis for Report

This report is based on an evaluation of existing data (both published and available unpublished data) collected from a variety of different sources. Some of the sources contacted during the preparation of this report include the U.S. Bureau of Land Management (BLM), the U.S. Geological Survey (USGS), the U.S. Bureau of Mines (USBM), the U.S. Department of Energy (DOE), the Wyoming Geological Survey, universities, and other sources listed in the references and selected bibliography section of this report.

The available literature was reviewed by a Project Team, assembled by the study contractor, comprised of authorities in the field of GEM resource evaluation. The members of the Project Team, and their associated technical disciplines, are identified below:

Mr. Charles S. Robinson	Metallic Minerals/Non-Metallic Minerals
Mr. Rollin E. Phipps	Oil and Gas
Mr. Andrew G. Alpha	Geothermal Resources
Mr. Stuart P. Hughes	Other Minerals
Mr. William A. Gallant	Other Minerals
Mr. Elmer M. Schell	Coal
Mr. John A. Hartley	Oil Shale/Paleontology



BLM Wilderness Study Areas Included in the Pryor Mountains GRA

WSA	NAME	ACREAGE
067–205	Burnt Timber Canyon	3,955
067–206	Pryor Mountain	16,972
067–207	Big Horn Tack-On	4,500

Approximate Boundary of Wilderness Study Area

NOTE: Contours in 200 ft. intervals.

(USGS, n.d.)
(USGS, 1954; limited revision, 1962)

Pryor Mountains GRA, Montana

TOPOGRAPHIC MAP

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FIGURE 1.2

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2.0 GEOLOGY

2.1 General

The geology of the Pryor Mountains GRA is illustrated on small and large scale geologic maps (Worchola and Stockton, 1982; Blackstone, 1940; Pierce, 1978). These maps, together with other available data, form the basis for certain conclusions regarding GEM resources in the study area.

The Pryor Mountains GRA occupies the south-central portion of the Billings 1° x 2° quadrangle, and the northeast portion of the Cody 1° x 2° quadrangle. The mountain mass that comprises the WSAs forms part of the northeastern margin of the Bighorn Basin; this mass is contiguous with the northern portion of the Bighorn Mountain range. The Pryor Mountains are composed of roughly rectangular structural blocks. These blocks are moderately dissected with steep slopes ending in abrupt scarps in the east, and gentle dip slopes in the west (Worchola and Stockton, 1982; Blackstone, 1940). Units from Mississippian (300-350 million years before present [m.y.B.P.]) through Lower Cretaceous (100-135 m.y.B.P.) age are exposed in the WSAs. Precambrian (> 600 m.y.B.P.) through Ordovician (440-500 m.y.B.P.) age rocks are buried beneath the exposed Mississippian and younger rocks.

2.2 Physiography

The Burnt Timber Canyon, Pryor Mountain, and Big Horn Tack-On WSAs fall within the Middle Rocky Mountain physiographic province (Fenneman, 1931). Altitudes within the WSAs range from approximately 3,900 feet near the southern end of the Pryor Mountain WSA, to 8,500 feet in the northern end of the WSAs. The climate also ranges from semiarid at lower altitudes to subalpine in the mountain areas. The area is drained on the west by the Clarks Fork of the Yellowstone River and on the east by the Bighorn River. Most of the precipitation in the area occurs as snow, with isolated periodic rainstorms that are typical of the Rocky Mountain region.

2.3 Geologic Units

A relatively complete stratigraphic section underlies the GRA. Bedrock units from Precambrian through Middle Cretaceous underlie the WSAs. Surficial deposits in the region consist of alluvial and colluvial deposits developed during recent geologic history. Figure 2.1, "Geologic Map," delineates the geologic formations that occur throughout the GRA. Figure 2.2, "Generalized Stratigraphic Column," is a generalized stratigraphic column which gives a brief description of all the stratigraphic units that underlie the Pryor Mountains GRA.

2.3.1 Bedrock Units

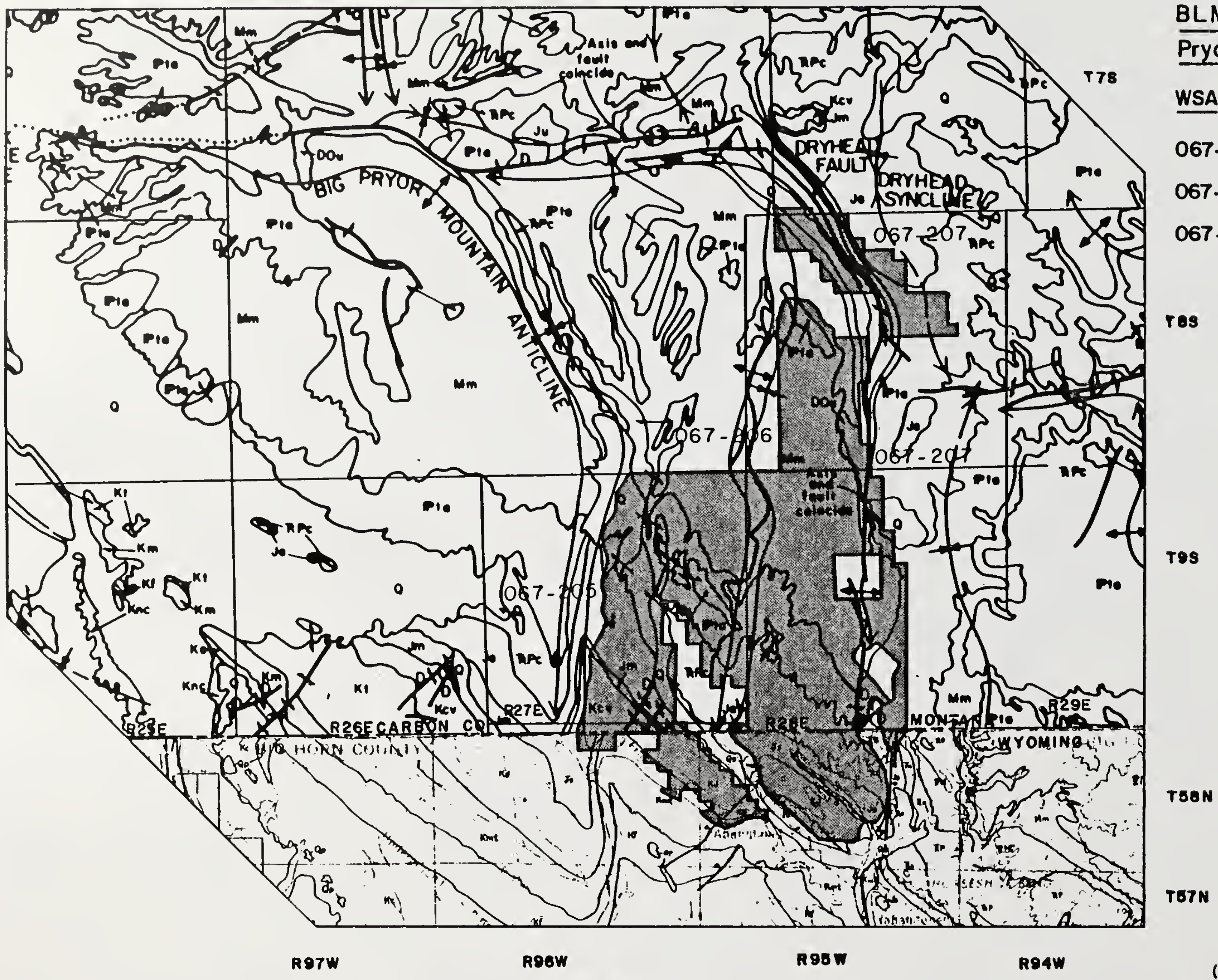
Precambrian (> 600 m.y.B.P.) through Ordovician (440-500 m.y.B.P.) rocks are not exposed within the boundaries of the WSAs; these units, however, do underlie the area. Descriptions of these units have been obtained from observations made in adjacent areas. The approximate thicknesses of each unit is illustrated on the generalized stratigraphic column (Figure 2.2).

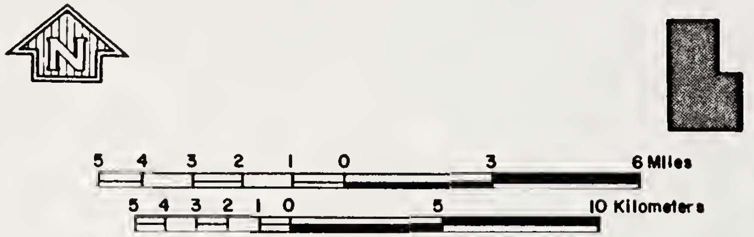
The Precambrian rocks of the region consist of granites and gneisses. No exposures are found in the Pryor Mountains. The Precambrian rocks in the Bighorn Mountains are probably similar to those that underlie the Pryor Mountains.

Overlying the Precambrian rocks are the Flathead Quartzite, the Gros Ventre Shale, and Gallatin Limestone of Cambrian (500-600 m.y.B.P.) age. The Flathead Quartzite consists of arkosic sandstone that weathers into sand. Overlying the basal Flathead Quartzite is the Gros Ventre Shale. The Gros Ventre Shale consists of glauconitic shales with minor thinly bedded limestones and flat pebble conglomerates. The Gallatin Limestone overlies the Gros Ventre Shale. The Gallatin Limestone consists of a flat pebble limestone conglomerate interbedded with shaley limestones.

BLM Wilderness Study Areas Included in the Pryor Mountains GRA

WSA	NAME	ACREAGE
067-205	Burnt Timber Canyon	3,955
067-206	Pryor Mountain	16,972
067-207	Big Horn Tack-On	4,500





▨ Approximate Boundary of Wilderness Study Area

(Pierce, 1978)
(Worchola and Stockton, 1982)

Pryor Mountains GRA, Montana

GEOLOGIC MAP

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FIGURE
2.1

SYSTEM	SERIES	SYMBOL		FORMATION		GENERAL LITHOLOGIC DESCRIPTION, FEET
QUATERNARY			Q		Undifferentiated Quaternary	
CRETACEOUS	Upper	KJ	Kc		Cody Shale	Shale, dark-gray, interbedded, with few thin sandstones, 250 feet
			Kf		Frontier Formation	Sandstone, gray- to light-brown, conglomeratic, black and brown chert pebbles 1/2-inch size, lenticular, interbedded with dark gray shale, 430-570 feet
	Lower		Kmt (Kl)		Mowry Shale	Shale, dark-gray, siliceous, two bentonite beds near top; shale, dark-gray, weathers silvery gray, siliceous, fissile, interbedded with thin white clay beds, 270-290 feet
					Thermopolis Shale	Shale, dark-gray, interbedded with yellow clay, with few zones of ironstone concretions; shale, dark-gray, dahllite concretions near base; shale, dark-gray, and bentonite; sandstone, gray, medium grained, 340-380 feet
			Kcv	CLOVERLY GROUP	Greybull Sandstone	Rusty sandstone, variegated claystone, 280-350 feet
					Fuson Shale	
					Lakota Sandstone	
JURASSIC			Jm		Morrison	Variecolored, siltstone, sandstone, and shale, 240 feet
			Je/Js	ELLIS GROUP SUNDANCE	Swift	Glauconitic sandstone at top; shale and claystone, gray green, 100 feet
					Rierdon	Limestone at top; shale and thin limestone beds, green, 150-170 feet
					Piper	Prominent basal gypsum bed; shale, red to pink, and thin limestone beds, 60-200 feet
TRIASSIC			TRPc		Chugwater	Siltstone, red; fine-grained sandstone, red; and thin red shale. Thin sandy limestone near base, 500-600 feet
PERMIAN					Embar (Phosphoria)	Hard, dense, white limestone and red siltstone, 10-60 feet
PENNSYLVANIAN			ℙta		Tensleep Sandstone	Sandstone, white to buff; cross laminated; nodular black chert in top part, 170 feet
					Amsden	Upper unit-argillaceous, dolomitic limestone and limey claystone, purple, 40 feet Lower unit-red claystone and siltstone; masses of hematite and occasional oolitic formation, 100 feet
MISSISSIPPIAN			Mm		Madison Limestone	Unit A-limestone, weathering gray to silver; fossiliferous canyon rim former. Fossil cave breccia, red, contains limestone blocks; filling of collapsed karst topography, 150-200 feet Unit B-dolomitic limestone, brown, usually finely crystalline, 200 feet Unit C-limestone, granular; in large part fossil "hash"; distinctive red to purple color. Thin bedded, ripple marks common; cross-bedded clastic limestone in some units, 90-100 feet Unit D-limestone, dark, 190 feet
DEVONIAN			DOu		Jefferson Dolomite	Dolomite, tan to brown. Lower part has yellowish-greenish cast on weathered surface. Some beds characterized by free-floating sand grains, 250-275 feet
					Beartooth Butte	Siltstone, red, contains angular blocks of white Bighorn dolomite. Occurs in channels cut into the underlying Bighorn dolomite, 0-40 feet
ORDOVICIAN					Bighorn Dolomite	Upper unit-dolomite; buff to white, thin-bedded argillaceous. Equivalent (?) to the Leigh member, 190 feet Lower unit-dolomite, massive, buff; reticulated weathering surfaces. Black chert in occasional nodules, 260 feet
CAMBRIAN			Єg		Gallatin Limestone	Flat-pebble or edgewise-pebble limestone conglomerate; green; glauconitic, 240 feet
			Єgv		Gros Ventre	Shale, green; few thin sandy shale beds. Source of major landslides, 450 feet
			Єf		Flathead Quartzite	Sandstone, red to brown; coarse grained; arkosic, 75 feet
PRECAMBRIAN			pЄ			Granitic gneiss; hornblende schist; quartz veins, and aplite dikes

Figure 2.2 Generalized Stratigraphic Column, Pryor Mountains, GRA. (Blackstone, 1940)

The Bighorn Dolomite of Ordovician (440-500 m.y.B.P.) age overlies the Cambrian Formations in the area. The Bighorn Dolomite consists of a massive cliff-forming dolomite interbedded with thinly bedded limestones in the upper part.

Geologic units younger than the Bighorn Dolomite crop out within the WSAs. These units consist of the Mississippian Madison Limestone; the Pennsylvanian (270-300 m.y.B.P.) Amsden Formation and Tensleep Sandstone; the Permian (225-270 m.y.B.P.) Embar Formation; the Triassic (180-225 m.y.B.P.) Chugwater Formation; the Jurassic (135-180 m.y.B.P.) Ellis Group and Morrison Formations; and the Cretaceous (70-135 m.y.B.P.) Cloverly Group.

The Madison Limestone of Mississippian age consists of thinly bedded massive purplish gray limestone, buff to brown limestone, karst collapse breccia, and gray to blue-gray fossiliferous cherty limestone. Overlying the Madison Limestone is the Amsden Formation of Mississippian and Pennsylvanian age. Throughout the area, the Lower Amsden Formation occupies solution features developed in the underlying Madison Limestone. The Amsden Formation consists of hard blocky, cherty, red and green shale, purplish shale with white and purple limestone, and thin beds of purplish to red and green thin sandstone shale and purplish limestone.

Overlying the Amsden Formation is the Tensleep Sandstone. The Tensleep Sandstone consists of tan to white, fine-grained crossbedded sandstones. Overlying the Tensleep Sandstone is the Permian Embar Formation that crops out over part of the WSAs. The Embar Formation consists of thin white siliceous limestones and red and yellow shales.

The Triassic Chugwater Formation overlies the Embar Formation where it is present in the study area; the Chugwater Formation also overlies the Tensleep Sandstone. The Chugwater Formation consists of red to maroon sandy shales, granular gypsum, and gray dense massive limestones.

The Sundance Formation (Ellis Group) of Jurassic age overlies the Chugwater Formation. The Sundance Formation (Blackstone, 1940) or Ellis Group

(Worchola and Stockton, 1982) consists of varicolored shales and siltstone (Piper Formation), gray calcareous shale (Rierdon Formation), and thin bedded glauconitic sandstones and black shale (Swift Formation). The Morrison Formation overlies the Ellis Group and consists of variegated siltstone, shale, and sandstone.

The Cretaceous units that overlie the Jurassic rocks consist of the Cloverly Group. The Clovery Group consists of Lakota Sandstone at the base (Pryor Conglomerate), overlain by varicolored sandstone, shale, and mudstones (Fuson Shale). Overlying the Lakota Sandstone and Fuson Shale is the Greybull Sandstone which consists of fine to medium grained sandstone.

2.3.2 Surficial Deposits

The surficial deposits of the region were formed during recent geologic time. Alluvial deposits consist of high level terrace deposits, developed during early stages of drainage development, and alluvium associated with present tributary streams. Colluvial deposits include talus, landslide deposits, and colluvium, which is bedrock weathered in place. Surficial deposits are not mapped in the area, although these deposits probably occur within the boundaries of the WSAs.

2.4 Structural Geology

The Pryor Mountains can be divided into four major units and three secondary units. Each of the four major units roughly form a square with a mountain block occupying each quadrant; the northeast quadrant is occupied by the northeast block, the northwest quadrant is occupied by West Pryor Mountain, the southeast quadrant is occupied by East Pryor Mountain, and the southwest quadrant is occupied by Big Pryor Mountain. The East Pryor Mountain block is favorable for the occurrence of uranium deposits in the Madison Limestone. The three secondary units of the Pryor Mountains are the Shively Hill Dome, which is east of the northeast block; the Sykes Spring area, which is south of East Pryor Mountain; and a monocline on East Pryor Mountain. The northern border of the square is the North Pryor Fault. The north and south quadrants are separated by the Sage Creek Fault. East-west quadrants are separated by the Crooked Creek Fault. The Sage Creek Fault is an echelon continuation of the Nye Bowler lineament, which is a regional feature. The WSAs are located principally within the East Pryor Mountain block.

2.5 Engineering Geology

The engineering geology of the WSAs is primarily concerned with rockfall hazards along the steep canyon walls. Flash flooding associated with canyons can occur in the area. Also, swelling soils and problems connected with vehicle transport are associated with the shaley rocks that underlie parts of the area.

2.6 Paleontologic Resources

Outcrops of the Chugwater, Sundance, Morrison, and Cloverly Formations crop out within the Pryor Mountains GRA. These formations have the potential for vertebrate fossil discoveries (Lillegraven, 1982). Dinosaur bones have been reported in the vicinity of the Burnt Timber Canyon WSA. Vertebrate remains have been found in caves existing in the Madison Limestone along the western slope of the Bighorn Mountains (i.e. Natural Trap Cave). No remains have been identified within the WSAs, but a significant potential exists for their presence (Gilbert et al., 1978; Martin and Gilbert, 1978).

2.7 Historical Geology

The geologic history of the Pryor Mountains area is similar to the geologic history of the middle Rocky Mountains. Basement Precambrian rocks in the region consist of metaigneous and metasedimentary rocks, the history of which is not well understood. At the end of Precambrian time and throughout the Paleozoic era (225 m.y.B.P.), there were repeated advances and retreats of the sea. Marine deposits of sandstone, shale and limestone were formed. At the end of the Paleozoic era, marine, marginal marine (evaporites), and terrestrial red-bed deposits were formed as the seas fluctuated back and forth over the area. Marine conditions returned in Jurassic time, only to retreat at the end of the Jurassic period. A major marine invasion started in early Cretaceous time and continued until the start of the Laramide orogeny near the end of the Cretaceous period. The Tertiary (2-70 m.y.B.P.) period was a time of repeated uplift accompanied by folding, thrusting, and high-angle faulting, and the deposition of thick terrestrial sediments in the intermountain basins (i.e. Pryor Mountains). Volcanism was active in mid to late Tertiary time and thick volcanic deposits accumulated locally and volcanic ash was distributed widely. This volcanic ash may have been a source rock for uranium, which may have migrated by groundwater into favorable rock units in the area. The Quaternary (2-3 m.y.B.P.) period is noted for widespread glaciation in the mountains and glacial outwash deposits along the flanks of the mountains.

3.0 ENERGY AND MINERAL RESOURCES

3.1 General

The Pryor Mountains GRA has a known past production of uranium and vanadium. The GRA has potential resources of two other GEM resources, gypsum and limestone.

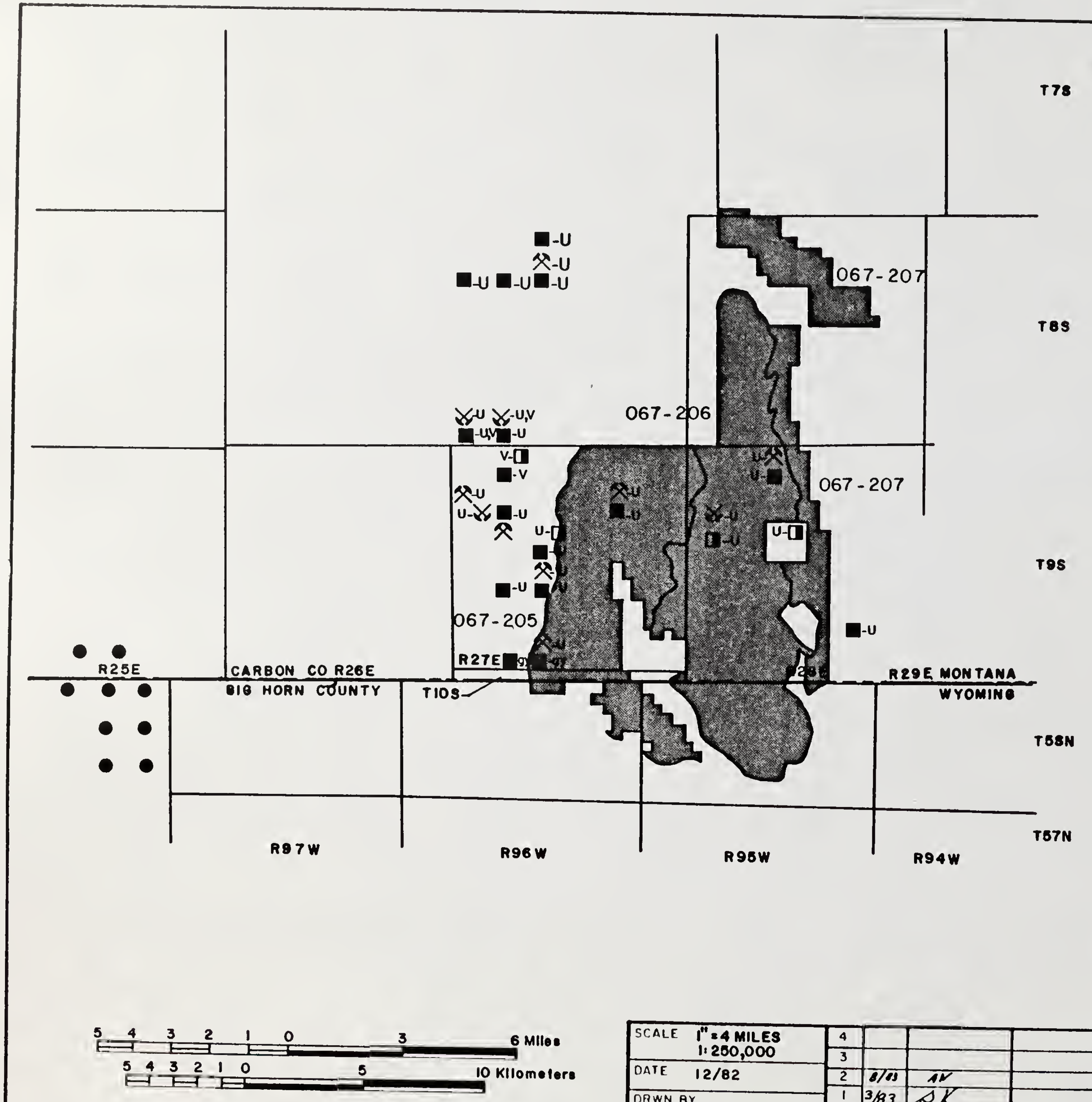
Figure 3.1, "Mineral Occurrence Map," illustrates the locations of any known past and present mine locations, or occurrences of mineral deposits and GEM resources within the GRA. Information for this figure came from the USGS' Computerized Resource Information Bank (CRIB); the USBMs Minerals Availability Information System (MILS); and Worchola and Stockton (1982).

3.2 Known Resources

The only known resource production adjacent to the Pryor Mountains GRA is uranium and vanadium from deposits associated with the Madison Limestone-Amsden contact zone (Worchola and Stockton, 1982; Garrand, Kopp, and Cohenour, 1982). The Pryor Mountains area has produced over 110,000 pounds of U_3O_8. Uranium was discovered in the area during the fall of 1955. Some of the better known producers have been the Swamp Frog Mine, Dandy Mine, Sandra Mine, Tishon Mine, and the Old Glory Mines. The deposits contained up to 8,000 tons

BLM Wilderness Study Areas Included in the Pryor Mountains GRA

WSA	NAME	ACREAGE
067-205	Burnt Timber Canyan	3,955
067-206	Pryor Mountain	16,972
067-207	Big Horn Tack-On	4,500



● Oil Wells
☼ Gas Wells
✸ Oil & Gas Well
⚒ Mines
⚔ Innactive Mines
■ Ore Body
◧ Deposit
▨ Appraximate Boundary of Wilderness Study Area

COMMODITY

u Uranium
v Vanadium
gy Gypsum

(USGS, 1982; USBM, 1982; Worchala and Stocktan, 1982; Garrand, Kopp, and Cohenaur, 1982)

Pryor Mountains GRA, Montana

MINERAL OCCURRENCE MAP

BLM GEM RESOURCES ASSESSMENT
REGION 6 WYOMING and MONTANA

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PASADENA, CALIFORNIA

FIGURE 3.1

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of uranium ore but most deposits were less than 500 tons. Deposits conformed to the size and shape of the cave or solution cavity in which they were contained. The grade of the ore was usually .50 percent uranium oxide (U_3O_8), and 1.5 percent vanadium oxide (V_2O_5). The ore had a high calcium carbonate content. The lime content was as high as 85-90 percent. Chemical assays averaged 25 percent more uranium than radiometric assays (Worchola and Stockton, 1982).

3.3 Potential Resources

The Tensleep Sandstone in the region is a permeable marginal marine sandstone with an available reductant (H_2S); this formation is an oil and gas producer to the west. It is also near high grade uranium source rock in the Pryor Mountains deposits; for example, the Tensleep Sandstone was buried beneath uraniferous rich Oligocene tuffs (Garrand, Kopp, and Cohenour, 1982).

Lakota Sandstone or Pryor conglomerates occur at the base of the Cloverly Group overlying the Morrison Formation. The Lakota Sandstone consists of a coarse grained quartzose sandstone and chert pebble conglomerate. Reductants would be in the form of hydrocarbons. There are several occurrences of uranium in this unit in areas adjacent to the GRA, notably in the Pryor Mountain WSA, and in other areas of the Bighorn Basin. In addition, anomalous radioactivity is shown on oil well logs from the area (Garrand, Kopp, and Cohenour, 1982). Lakota Sandstone may only underlie a small portion of the Pryor Mountain WSA, near the southern margin of the WSA near the Crooked Creek scenic area.

Gypsum occurs in the Chugwater Formation of Triassic age and limestone occurs as extensive deposits in the Madison Limestone of Mississippian age (Blackstone, 1940; Worchola and Stockton, 1982; Pierce, 1978).

3.4 Land Status

Most of the unpatented claims in the Pryor Mountains GRA lie along the boundary between the Burnt Timber Canyon and Pryor Mountain WSAs. There are a few patented claims east of the three WSAs, and oil and gas leases are found west and south of the WSAs. Figure 3.2, "Claim and Lease Map," illustrates the locations of any oil and gas leases, patented claims, and unpatented claims in the Pryor Mountains GRA.

3.5 Deposit Types

The uranium and vanadium deposits in the study area are small to moderate in size and are restricted to the contact between the Madison Limestone and Amsden Formation. The uranium and vanadium occurrences and deposits in the Pryor Mountains contain secondary uranium minerals deposited in solution cavities and brecciated collapse structures. The sources for this uranium have been postulated as being either uranium rich hydrothermal solutions which percolated through the regional fracture pattern and deposited the uranium at reduced zones, or from meteoric waters which leached uranium from volcanic tuffs that blanketed the area during the Tertiary.

Uranium deposits may occur in the form of peneconcordant or roll front types in the Tensleep and Lakota Sandstones. These deposits can occur where uraniferous groundwater intercepts reductant zones. Reductants zones can be caused by hydrogen sulfide, hydrocarbons, and carbonaceous material. Structurally, roll front types of deposits might be expected.

Limestone is abundant within the WSAs and in the surrounding region from the Madison Limestone. The limestone is a precipitate and is generally very pure calcium carbonate. Gypsum in the Chugwater Formation was deposited as an evaporite and is mined in other parts of the Bighorn Basin. The quality and thickness of the resource is highly variable.

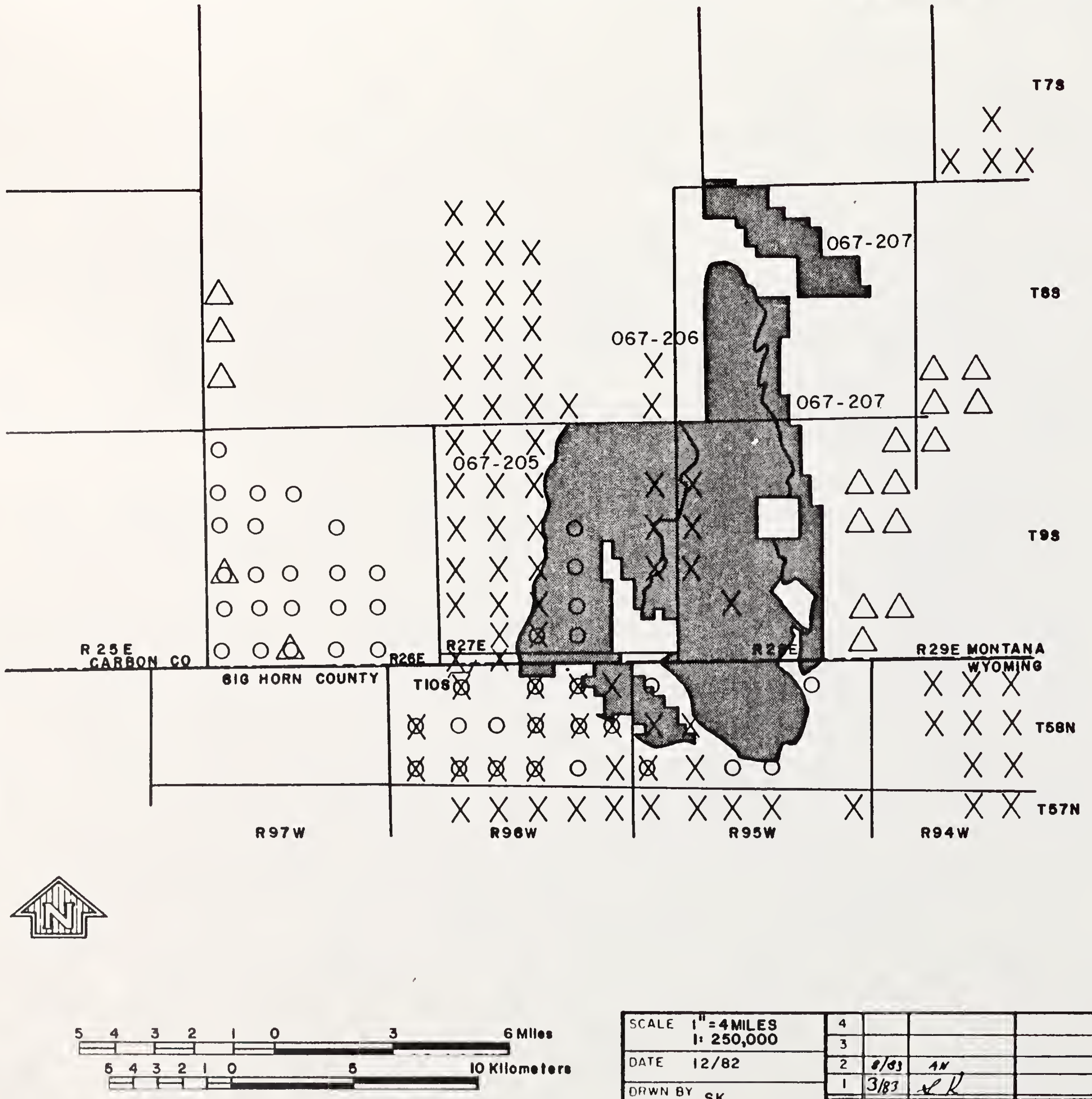
3.6 Resource Economics

3.6.1 Strategic Minerals

Vanadium is the only strategic or critical mineral resource with a potential occurrence in this GRA. Vanadium is important as an alloying agent for

BLM Wilderness Study Areas Included in the Pryor Mountains GRA

WSA	NAME	ACREAGE
067-205	Burnt Timber Canyon	3,955
067-206	Pryor Mountain	16,972
067-207	Big Horn Tack-On	4,500



○ Oil & Gas Lease

△ Patented Claim

X Unpatented Claim

▨ Approximate Boundary of Wilderness Study Area

NOTE: Symbols illustrate those sections where claims or leases are present

(BLM, 1982)

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Pryor Mountains GRA, Montana

CLAM and LEASE MAP

BLM GEM RESOURCES ASSESSMENT

REGION 6 WYOMING and MONTANA

TETRA TECH INC.

PASADENA, CALIFORNIA

FIGURE 3.2

iron and steel and is used in the production of titanium alloys. The U.S. imported approximately 25 percent of the vanadium it used in 1978. This share of imports has probably increased since then.

In 1980, vanadium (V_2O_5) was selling at $3.54 per pound; in 1981, the price for vanadium was estimated to be $3.52 per pound. With the depressed economy and the large drop in steel consumption and other activities, it is probable that the price and consumption of vanadium have dropped below even the 1981 figure. With an upturn in the national economy and the subsequent increase in demand for vanadium, vanadium resources in this area will receive more attention.

3.6.2 Industrial Minerals

Gypsum

Average calcine gypsum was selling for $22.82 per ton in 1980; in 1981, the price was estimated to be $23.73 per ton. Since then, there has been a large decline in the construction industry. Recent signs, however, seem to indicate that this industry is recovering slowly.

Limestone

Limestone sold for $2.88-3.20 per ton in 1980; this price reflects the general inflationary environment of 1981 and 1982. The major use of limestone is in the construction industry which has been seriously hurt by the recession. Recent increases in housing permits and other construction projects should increase the demand for limestone.

3.6.3 Uranium

The current price of uranium (approximately $17 per pound in October, 1982) is low enough to discourage additional mining and exploration. A turnaround in national nuclear policy will be necessary to return the industry to profitability. Reserves far exceed demand at present and numerous mines with significant measured reserves of U_3O_8 have closed due to the low demand for uranium and high production costs. When and if nuclear policy and attitudes change, the uranium industry will recover slowly, but probably not to the level of the 1970s.

4.0 LAND CLASSIFICATION FOR GEM RESOURCE POTENTIAL

4.1 General

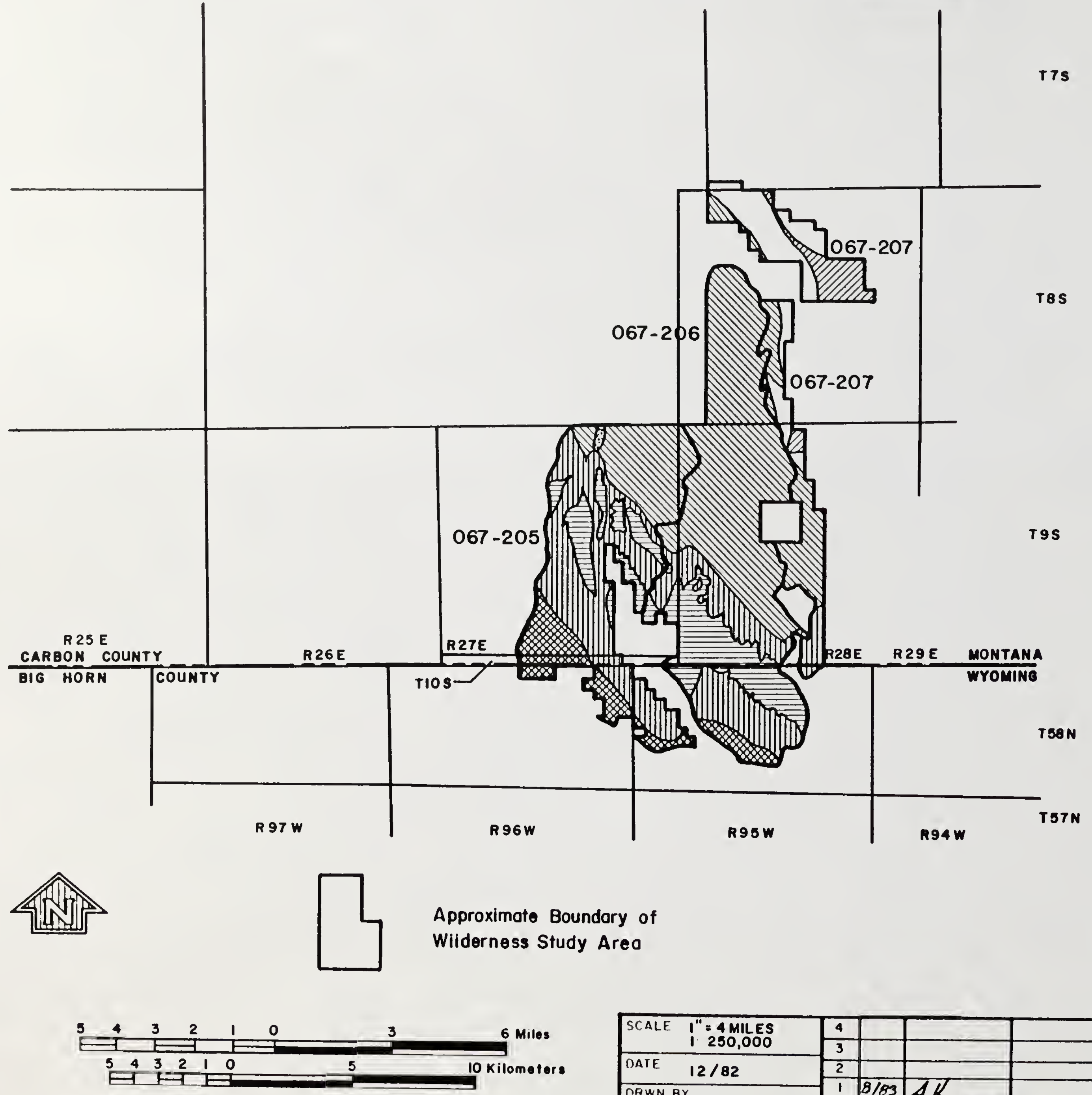
The WSAs within the Pryor Mountains GRA have geologic environments favorable for the occurrence of uranium, vanadium, gypsum, and limestone. The known geologic environment and the inferred geologic processes in the WSAs do not indicate a favorable environment for the accumulation of other GEM resources.

In order to better evaluate the occurrence or potential occurrence of resources in the GRA, a 2-part resource classification scheme has been adopted as requested by contract. Each resource or potential resource within the GRA will receive an alpha-numeric designation. The number designation will range from 1 to 4, and will indicate the favorability of the geologic environment, geologic processes, and mineral occurrences for the presence of a particular resource or group of resources. The letter designation will range from A to D, and will indicate the level of confidence to be associated with the numerical designation. Figure 4.1, "Land Classification Map," illustrates the areas of potential GEM resources with their assigned classifications for the WSAs within the Pryor Mountains GRA. Figure 4.2, "Resource Classification Scheme," provides a detailed description of the number and letter designations used in the resource classification scheme.

4.2 Metallic Minerals

4.2.1 Uranium and Vanadium

Areas of the Pryor Mountains GRA are considered to have a high favorability based on abundant direct and indirect evidence for the potential occurrence of uranium and vanadium (classified 4D). This high favorability exists in those areas where the Madison Limestone/Amsden contact zone crops out and down dip.



BLM Wilderness Study Areas Included in the Pryor Mountains GRA

WSA	NAME	ACREAGE
067-205	Burnt Timber Canyon	3,955
067-206	Pryor Mountain	16,972
067-207	Big Horn Tack-On	4,500

SYMBOL	GEM RESOURCE	CLASSIFICATION
▧	Uranium & Vanadium Limestone Other GEM Resources	4D 3D 2C
░	Uranium & Vanadium Limestone Gypsum Other GEM Resources	4D 3D 3D 2C
▩	Uranium & Vanadium Uranium & Vanadium Limestone Other GEM Resources	4D 3B 3D 2C
▥	Uranium & Vanadium Uranium & Vanadium Limestone Other GEM Resources	4D 3B 3D 2C
▤	Uranium & Vanadium Uranium & Vanadium Limestone Gypsum Other GEM Resources	4D 3B 3D 3D 2C
▨	Gypsum Other GEM Resources	3D 2C
☐	Other GEM Resources	2C

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Pryor Mountains GRA, Montana

LAND CLASSIFICATION MAP

BLM GEM RESOURCES ASSESSMENT
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FIGURE
4.1

Numerical Classification Scheme

1) The geologic environment and the inferred geologic processes do not indicate favorability for accumulation of mineral resources.

2) The geologic environment and the inferred geologic processes indicate low favorability for accumulation of mineral resources.

3) The geologic environment, the inferred geologic processes, and the reported mineral occurrences indicate moderate favorability for accumulation of mineral resources.

4) The geologic environment, the inferred geologic processes, the reported mineral occurrences, and the known mines or deposits indicate high favorability for accumulation of mineral resources.

Letter Classification Scheme (Level of Confidence)

A) The available data are either insufficient and/or cannot be considered as direct evidence to support or refute the possible existence of mineral resources within the respective area.

B) The available data provide indirect evidence to support or refute the possible existence of mineral resources.

C) The available data provide direct evidence, but are quantitatively minimal to support or refute the possible existence of mineral resources.

D) The available data provide abundant direct and indirect evidence to support or refute the possible existence of mineral resources.

Figure 4.2 Resource Classification Scheme

This classification is based upon known production and occurrences of these resources, and the presense of favorable geologic environments within the WSAs (Worchola and Stockton, 1982). Other areas of the Pryor Mountains GRA are considered to have a moderate favorability based on indirect evidence for the potential occurrence of uranium and vanadium (classified 3B). This moderate favorability exists in those areas where the Tensleep and Lakota Sandstones crop out and down dip. This classification is based upon known occurrences of uranium in the area, and the presence of favorable geologic environments for the accumulation of uranium (Worchola and Stockton, 1982; Garrand, Kopp, and Cohenour, 1982).

4.3 Industrial Minerals

4.3.1 Gypsum

The Pryor Mountains GRA is considered to have a moderate favorability based on abundant direct and indirect evidence for the potential occurrence of gypsum (classified 3D); this classification is based upon the common occurrence of gypsum in the Chugwater Formation, and vast reserves of this resource found elsewhere in the Rocky Mountain region (Pierce, 1978).

4.3.2 Limestone

The Pryor Mountains GRA is considered to have a moderate favorability based on abundant direct and indirect evidence for the potential occurrence of limestone (classified 3D); this classification is based on the common occurrence and high quality of limestone in the Madison Limestone, and the presence of vast reserves of this resource elsewhere in the Rocky Mountain region (Worchola and Stockton, 1982).

4.4 Other GEM Resources

Quantitatively minimal direct evidence exists to support a low favorability classification for the potential occurrence of other GEM resources in the WSAs (classified 2C). This classification is based on the geologic environment and inferred geologic processes that have been identified within the WSAs.

5.0 RECOMMENDATIONS FOR FURTHER WORK

5.1 Work Recommended to Complete Data Base

A number of investigations could be implemented to generate additional data to supplement the conclusions of this Phase I report for the Pryor Mountains GRA. Detailed mapping of potentially favorable paleokarst terrain would assist in identifying the old erosion surface that was exposed in the area during the uranium mineralization episode. Also, an evaluation of the gypsum resources of the area should be performed by measuring thickness and facies changes in the Chugwater Formation.

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